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Making More Informed Decisions in Your Watershed When Dollars Aren't Enough

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January 1998
IWR Report 98-R-1

Decision Support
Technologies Research Program

U.S. Army Institute for Water Resources
Technical Analysis and Research Division

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- *Cost Effectiveness and Incremental Cost Analyses*
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MAKING MORE INFORMED DECISIONS IN YOUR WATERSHED WHEN DOLLARS AREN'T ENOUGH

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PREFACE

Decisions regarding potential investments in watershed resources can leave decision makers comparing "apples to oranges" when the costs of watershed improvements are measurable in dollars but the benefits are not. While traditional benefit-cost analysis simply won't work in these situations, the tools of cost effectiveness analysis and incremental cost analysis can help by providing information to support decision making. This paper presents a general analytical procedure for cost effectiveness and incremental cost analyses and three example applications. The examples demonstrate the procedures applicability to planning for investments in a variety of resources, as well as to problem solving situations of different complexities.

This paper was presented at the Fifth National Watershed Coalition Conference in Reno, Nevada, on 20 May 1997. The Conference theme was "Living in Your Watershed". The authors appreciate the opportunity to participate in the Conference and thank Mr. Richard G. Jones, the Immediate Past Chairman of the National Watershed Coalition, and Mr. John Peterson, the Coalition's Executive Director, for their support and permission to reprint this paper.

The work presented in this paper was conducted as part of the Decision Support Technologies Research Program. The Program is sponsored by the Headquarters, U.S. Army Corps of Engineers and is assigned to the Water Resources Support Center, Institute for Water Resources. Mr. Michael Krouse is the Program Manager at the Institute for Water Resources. Mr. Robert Daniel, Planning Division, Mr. Jerry Foster, Engineering Division, and Mr. Harold Tohlen, Operations, Construction and Readiness Division, are the Headquarters' Program Monitors. Field Review Group Members that provide overall Program direction include: Mr. William Fickel of the Fort Worth District, Mr. Martin Hudson of the Rock Island District, Mr. Matt Laws of the Charleston District, and Ms. Pat Obradovich of the Portland District. This paper was prepared under the general supervision of Mr. Michael Krouse, Chief of the Technical Analysis and Research Division, Institute for Water Resources, and Mr. Kyle Schilling, Director of the Institute for Water Resources and Acting Director of the Water Resources Support Center.

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Making More Informed Decisions in Your Watershed When Dollars Aren't Enough

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Abstract: Decisions regarding potential investments in watershed resources can leave decision makers comparing "apples to oranges" when the costs of watershed improvements are measurable in dollars but the benefits are not. Additionally, in such cases traditional cost benefit analysis cannot be used to identify an "optimal" solution. However, the analytical tools of cost effectiveness and incremental cost analyses can assist in the selection of a single plan by providing information to support decision making. After describing the analytical procedures, three example applications of the analyses will be summarized to demonstrate the types of information they can provide. The examples (pertaining to hazardous materials cleanup, lake fishery habitat restoration, and historic preservation) demonstrate the procedures' applicability to planning for investments in a variety of resources as well as to problem solving situations of differing complexity: *What's the best combination of single solutions at multiple sites? What's the best solution at a single site?* and *What's the best combination of multiple solutions at multiple sites?*

Watershed Investment Decisions

Watersheds provide communities with many desired services. Some of these services, or watershed "outputs", do not lend themselves to being valued in dollars. Examples of such outputs include water quality, fish and wildlife habitat, and aesthetics. While methodologies – such as the contingent valuation method – exist for estimating the dollar value of such resources, obtaining accurate results can be prohibitively costly in some situations. In addition, even an accurate dollar estimate of a resource's value may be challenged and disputed.

In situations where it is not practical to measure watershed outputs in dollars, the outputs can be measured using other, often less controversial, metrics like "acres" or "population counts". However, when solutions' costs and benefits are measured in different units (for example, costs in dollars and benefits in acres of wetlands), traditional cost benefit analysis becomes unusable and there is no decision rule identifying an "optimal" solution. Still, decisions must be made about what level of investment (if any) is desirable.

The tools of cost effectiveness and incremental cost analyses provide a framework for comparing the dollar costs and the non-dollar outputs associated with alternative solutions to specific problems. The analyses make the available options and their tradeoffs more explicit, providing information that supports the decision of what level of investment is desirable and affordable; or in other words – "worth it". Just as important, the tools provide an organized methodology which focuses planners on identifying alternative solutions, examining how well they accomplish planning objectives, and at what cost. The analyses require three types of data: alternative solutions, estimates of each solution's output, and estimates of each solution's cost.

Solutions refer to ways of solving problems – or in other words, ways of accomplishing planning objectives. Watershed solutions might be to "*create wetlands*," or to "*install 50 nesting boxes in the riparian zone*." Cost effectiveness and incremental cost analyses are tools for comparing alternative solutions to a problem and identifying their differences – specifically differences in their output and in their cost.

Output can be measured in many metrics – some examples of non-monetary measurement units include acres, river-miles, acre-feet, and population counts. Output measurements may also be derived by applying models such as the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures, which measure habitat quantity and quality for specific species in "habitat units". Output for the two solutions listed in the above paragraph might be measured in "*acres*," and "*breeding pairs of ducks*," respectively.

Cost estimates should include financial implementation costs (for example, costs of design, construction, real estate acquisition, operation, maintenance, and monitoring) as well as any opportunity costs of economic benefits existing with the current state of the watershed that would be forgone if a solution is implemented. For example, a solution to restore 100 acres of wetlands above a city might cause some existing flood control benefits to be given up – this opportunity cost needs to be considered in evaluating the merits of the investment in wetlands. Similarly, a solution might provide incidental economic benefits. If a solution to restore 100 acres of wetlands incidentally will provide water supply benefits by recharging groundwater tables, the increase in water supply can be considered an incidental benefit. Incidental benefits can be accounted for in cost effectiveness and incremental cost analyses by subtracting them from the sum of implementation costs and opportunity costs.

Cost effectiveness analysis identifies the least cost solution for each possible level of output under consideration as well as those solutions which provide more output for equal or less cost than others. Subsequent incremental cost analysis reveals the increases in cost that accompany increases in output, identifying those solutions which provide the greatest return in output per dollar invested, or "best-buys". Application of these tools assists stakeholders and decision makers by framing the question: "As we increase the scale of this project, is each subsequent level of additional output worth its additional cost?"

To illustrate the analyses' application, consider a hypothetical case where a group of stakeholders have pooled their resources to restore wetlands within their local watershed. After identifying seven alternative solutions for wetland restoration, the planning team must decide which solution is most desirable. They agreed that output would be measured by the *acres of wetlands* resulting from each plan. At a team meeting following a visit to potential restoration sites, the team was able to compile cost and output estimates for each of the seven plans. Table 1 lists the seven solutions with their cost and output estimates. With the information in Table 1 in hand, the planning team is ready to conduct a cost effectiveness analysis and an incremental cost analysis of the proposed solutions to inform their decision making process.

Cost Effectiveness Analysis

In cost effectiveness analysis, solutions are identified as "cost effective" if they pass two screening tests:

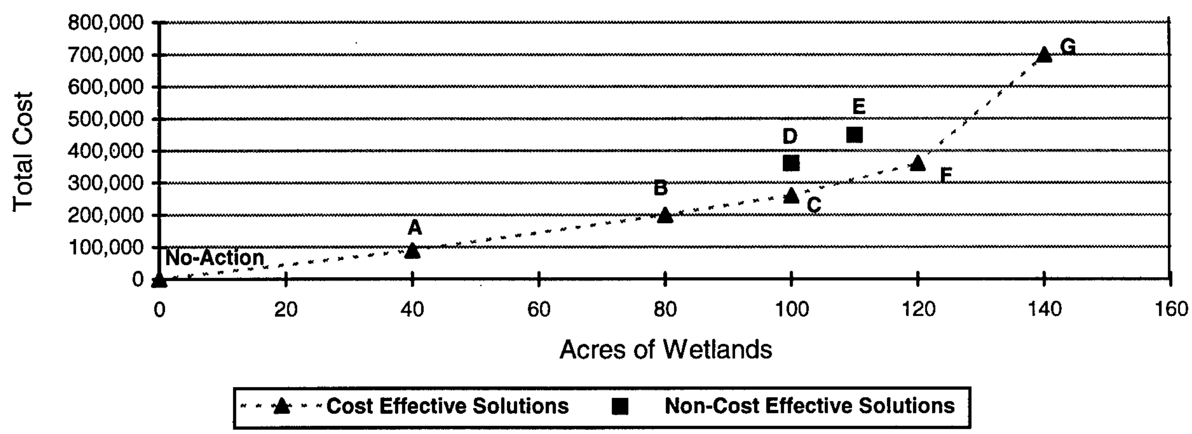
1. No other solution provides the same output for less cost; and
2. No other solution provides more output for the same or less cost.

Notice that in Table 1, Restoration Plans D and E are shaded over to indicate that they are not cost effective. Plan D fails to meet screening test number one – why spend $360,000 for 100 acres of restored wetlands when Plan C provides the same level of output for $100,000 less? Plan E fails to meet screening test number two – why spend $450,000 for 110 acres of restored wetlands when Plan F provides 120 acres for only $360,000? The relationships identified through cost effectiveness analysis can be plotted graphically as in Figure 1. Plans identified as non-cost effective, in this case plans D and E, are set aside during subsequent incremental cost analysis.

TABLE 1: Wetlands Restoration – All Solutions
Cost Effectiveness Analysis (shading over non-cost effective solutions)

Solutions:	Total Cost ($):	Total Output (acres):
No Action Plan (no restoration)	0	0
Restoration Plan A	90,000	40
Restoration Plan B	200,000	80
Restoration Plan C	260,000	100
Restoration Plan D	360,000	100
Restoration Plan E	450,000	110
Restoration Plan F	360,000	120
Restoration Plan G	700,000	140

FIGURE 1: Wetlands Restoration - All Solutions
Cost Effectiveness Analysis Display



Incremental Cost Analysis

Incremental cost analysis is an investigation of how the costs of additional output increase as output increases. By explicitly identifying the cost and output differences across the cost effective solutions, we can address the selection of what level of output is worth its cost. While total cost and total output information were adequate for cost effectiveness analysis, incremental cost analysis requires additional calculations to identify the differences across solutions. These additional calculations involve the change in output and the corresponding change in cost from solution to solution. These calculations of change result in the "incremental" values found in Table 2.

In Table 2, the column labeled incremental cost is the change in cost associated with each plan divided by the corresponding change in output. Incremental cost is defined here as the unit cost of the additional output a solution provides over a smaller-scaled solution. For example, by moving from the No Action solution to Plan A, 40 additional acres of wetlands can be gained at an additional cost of $90,000 – the additional acres come at an incremental cost of $2,250 per acre. If the first 40 acres are decided to be worth $2,250 each, then look to the next plan, Plan B, which provides an additional 40 acres for an additional $110,000. The incremental cost of the 40 additional acres obtainable with Plan B is slightly higher than the incremental cost of Plan A – providing the additional acres at $2,750 each.

If you scan down the "Output," "Change in Output" and "Incremental Cost" columns in Table 2, you can notice that, in this example, as output is increased by moving to each successively larger plan, each consecutive increment of additional acreage comes at a higher cost per acre. This incremental cost information can help decision makers choose which plan is most desirable in terms of both output and cost. This incremental cost information can be shown graphically as in the box chart in Figure 2.

In this chart, the width of each box corresponds to the additional output provided by each respective plan, the height of each box corresponds to the incremental cost of that additional output. The area of each box corresponds to the total change in cost occurring as each respective plan is selected instead of the preceding plan. Such an incremental cost display can assist decision makers in determining when, if at all, additional units of output are no longer worth their cost.

TABLE 2: Wetlands Restoration – Incremental Cost Analysis

Solutions:	Total Cost ($)	Output (acres)	Change in Cost ($)	Change in Output (acres)	Incremental Cost ($/acre)
No-Action	0	0	--	--	--
Plan A	90,000	40	90,000	40	2,250
Plan B	200,000	80	110,000	40	2,750
Plan C	260,000	100	60,000	20	3,000
Plan F	360,000	120	100,000	20	5,000
Plan G	700,000	140	340,000	20	17,000

FIGURE 2: Wetlands Restoration - Cost Effective Solutions
Incremental Cost Analysis Display

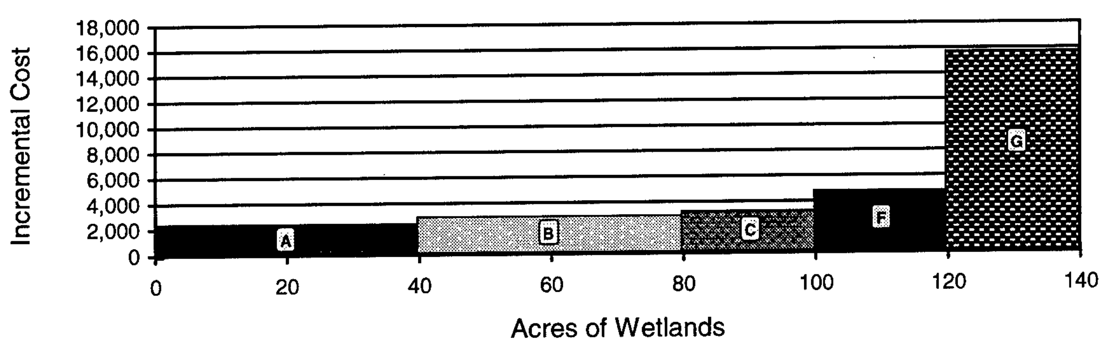


Table 2 and Figure 2 each show that, in this example, incremental costs slowly increase as output is increased to 100 acres of wetlands – the first 40 acres cost $2,250 each, the second 40 cost $2,750 each, and the next 20 cost $3,000 each. The jump in incremental cost is higher as we move from 100 to 120 acres – $5,000 each. And the final 20 acres come at a much higher incremental cost – $17,000 each.

While cost effectiveness and incremental cost analyses will not identify an optimal solution (for example, one that maximizes net benefits) as is the case with benefit-cost analysis, they do organize and present information that can facilitate the informed selection of a single solution. This selection may also be guided by other decision guidelines such as output targets (legislative requirements or regulatory standards), minimum and maximum output thresholds, budget constraints, uncertainty in cost and output estimates, and consideration of the unintended effects of solutions on other resources.

Three Example Applications of the Analyses to Three Different Problem Solving Cases

The following pages present three example applications of a step-by-step procedure for formulating alternative combinations of solutions (or "plans") and comparing them through cost effectiveness and incremental cost analyses. The steps of the procedure, developed at the U.S. Army Corps of Engineers Institute for Water Resources, are documented in a procedures manual and case study, and are incorporated into the software programs - ECO-EASY: Cost Effectiveness and Incremental Cost Analyses Software, and IWR-PLAN Decision Support Software.

The three examples are based on actual studies and projects involving hazardous material cleanup (Example A), lake habitat restoration (Example B), and battlefield park improvements (Example C). The examples' outputs are measured in non-dollar units like cleanup points (Example A), habitat units (Example B), and historic value index units (Example C). The different examples also show the procedure's applicability across a range of analytical complexity, from a set of independent sites with no combinability or dependency constraints (see formulation section below) among sites (Example A), to a more complex situation involving multiple sites, multiple scales of solutions, and both combinability and dependency constraints (Example C).

The examples are intended to highlight two features of the procedure. The first feature is the procedure's applicability to any quantifiable output measurement unit; whether it be acres, cleanup points, habitat units, historic value index units, percentages of dissolved chemicals, congestion index units, or any other unit of measurement that is consistent across solutions. The second feature is the procedure's applicability to different types of problem solving situations; whether it is determining the best solution at a site, the best mix of best solutions at different sites throughout a watershed or region, the best mix of different potential solutions at different sites, or other problem solving scenarios. While circumstances and results vary with every planning situation, the examples demonstrate how the procedure can help planners with the formulation, comparison, screening and selection of plans.

Formulation - Given a set of solutions to a problem, the procedure will formulate every possible combination of those solutions (accounting for cases of non-combinability and dependency). Solutions are combinable if they can be implemented together in a single plan. Solutions are not combinable if implementing one precludes the implementation of the other. A solution is dependent on another if it would not function as intended unless the other solution was also implemented. This "all possible combinations" approach to plan formulation will ensure that no alternative plan combination is overlooked given a fixed set of individual solutions. In the examples, the procedure combined solutions to formulate 1,024, 192 and 1,296 different alternative plans, respectively.

Screening - Next, the procedure will compare the costs and outputs of alternative plans, identifying plans that are, first, not cost effective; and second, not cost efficient (or not "best buys"). Best buys are the subset of the cost effective plans which are the most efficient plans at producing output as project scale is increased - they provide the greatest increase in output for the least increase in cost. These screening steps typically reduce even a very large number of possible alternative plans to a much smaller and more manageable set of superior investments. In the examples, the analyses reduced the number of alternative plans to 10, 6 and 9 best buy plans, respectively.

Selection - Finally, the procedures' comparisons of costs and outputs can provide decision makers with a basis for selecting a final plan over other alternatives. The results, in conjunction with the decision guidelines described above, can help decision makers determine what levels of output are "worth it?" and guide the final selection decision. While no rule exists – for example, saying that a cost effective or a best-buy plan must be selected – the results of the analyses make the tradeoffs across alternative solutions more explicit.

What's the best combination of single solutions at multiple sites?
Example A – Hazardous Materials Cleanup

Planning Problem. Ten leaking underground storage tanks were identified for cleanup in a southwestern state. The state agency wished to prioritize the sites to identify what mix of sites would provide the greatest cleanup benefit for their budget.

TABLE 3: Solutions, Costs and Outputs

Cleanup Sites	Costs ($1,000)	Outputs (Points Reduced)
No Action	0	0
Site 1	45	270
Site 2	35	150
Site 3	80	900
Site 4	5	15
Site 5	20	250
Site 6	60	200
Site 7	55	400
Site 8	5	100
Site 9	40	350
Site 10	80	500

Solutions, Costs and Outputs. Solutions at the ten sites consisted of a variety of corrective actions - all designed to achieve 100% cleanup. Implementation costs were estimated for cleaning up each site. Cleanup benefits were measured using a point scoring system that measured the adverse effects of sites based upon proximity to groundwater tables, habitat, and other factors. Benefit scores represented the number of points that a cleanup action would reduce at a site. Table 3 lists the sites and each site's cleanup costs and outputs.

Formulation. All sites were combinable and none were dependent on any others being implemented first. All possible combinations of the ten sites would formulate 1,024 alternative plans. Figure 3-1 displays the full range of possible plans.

Screening. Fifty-six of the 1,024 possible plans were identified as cost effective plans; 10 of those were identified as best buy plans. Figure 3-2 displays the cost effective and best buy plans. Figure 3-3 displays the best buy plans' incremental costs. The best buys are the range of plans that are the best investments for achieving cleanup points. Note that this problem – ordering the implementation of single solutions at multiple sites without dependency or combinability constraints – is the simplest type of problem situation, where the 10 best buys could be identified simply by ranking the sites in order of increasing average cost; however, with that approach the other 46 cost effective combinations of sites would not have been identified.

FIGURE 3-1: All 1,024 Alternative Cleanup Plans

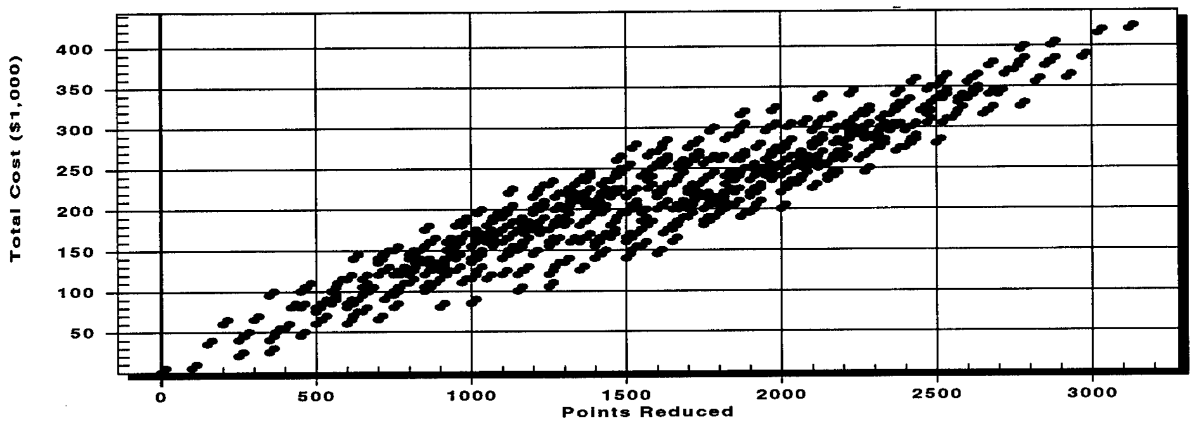


FIGURE 3-2: 56 Cost Effective Cleanup Plans (10 Best Buys are indicated by stars)

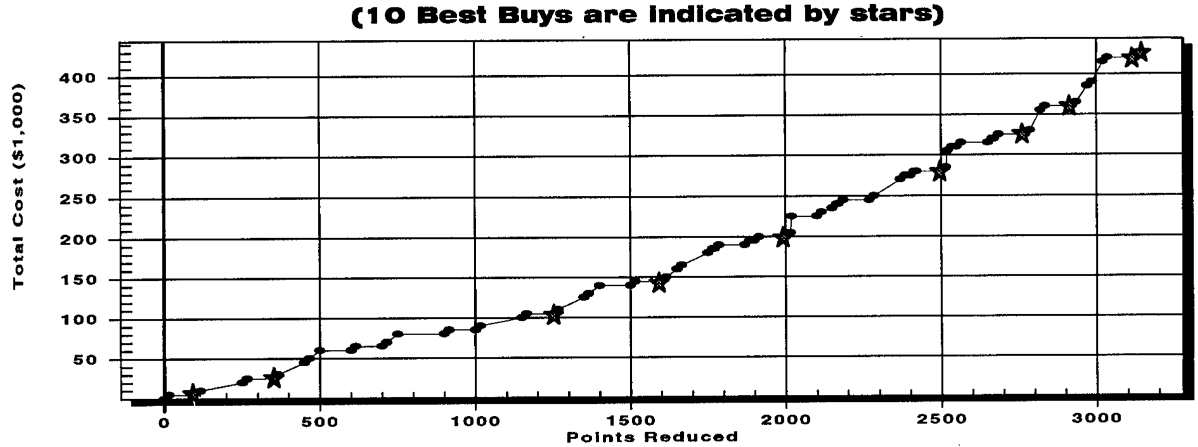
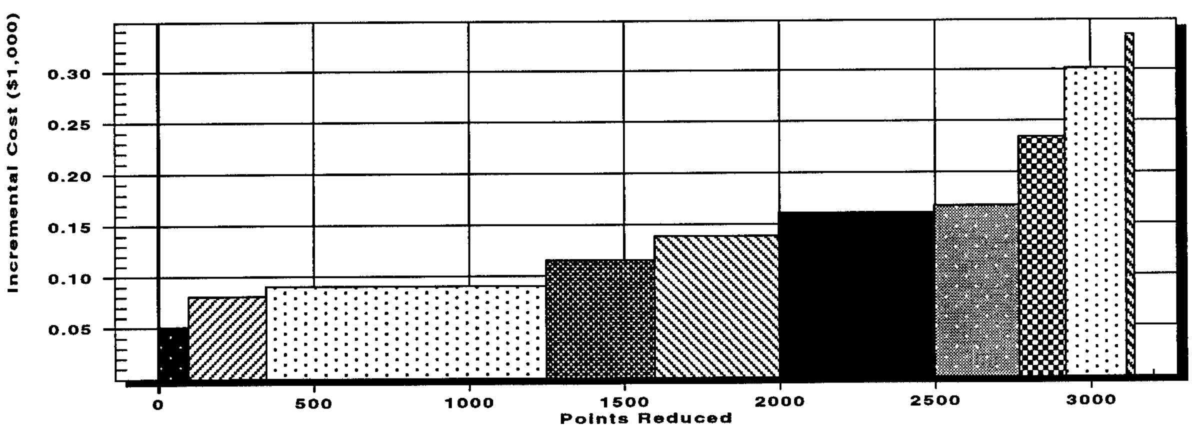


FIGURE 3-3: Incremental Costs of 10 Best Buy Cleanup Plans



What's the best solution at a single site?
Example B – Lake Habitat Restoration

Planning Problem. Sedimentation in a backwater lake along the upper Mississippi River reduced water depths to the point where fish habitat quality was declining. A joint Federal-state study was undertaken to explore solutions for restoring the lake's fishery habitat before its decline became irreversible.

Solutions, Costs and Outputs. Four different management measures for habitat restoration were considered: aeration (1 size of pump was considered), substrate improvement (1 sized area was considered), aquatic plant harvesting (5 different sized areas were considered), and dredging (7 different volumes of material to be removed were considered). Costs for these measures included costs for initial equipment and labor, replacement equipment, annual labor, and annual operation and maintenance; costs were converted to an average annual equivalent basis. Habitat outputs were measured in habitat units for the bluegill fish species using the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures and converted to an average annual basis. Table 4 lists the measures with their costs and outputs.

TABLE 4: Solutions, Costs and Outputs

Restoration Measures		Costs ($1000)	Outputs (habitat units)
No Action		0.0	0
Aeration		9.7	22
Substrate improvement		53.6	1
Harvesting	21 acres	23.4	4
	42 acres	25.9	5
	63 acres	28.5	11
	85 acres	30.0	14
	106 acres	30.8	16
Dredging	140,000 cubic yards	101.6	24
	185,000 cubic yards	122.7	28
	220,000 cubic yards	176.2	33
	245,000 cubic yards	191.1	41
	255,000 cubic yards	196.1	42
	270,000 cubic yards	205.2	44
	310,000 cubic yards	227.2	48

Formulation. In this case, 4 habitat restoration measures (one measure with 5 different levels, or "scales", and another measure with 7 scales) were being considered at a single geographical site. The four habitat restoration measures were combinable, and none were dependent on any other measures being in place first. Therefore, the measures could be combined to formulate 192 possible alternative plans. Figure 4-1 displays the full range of possible plans. Cost effectiveness and incremental cost analyses were conducted to compare the effects of each alternative plan.

Screening. Twenty-six of the 192 possible plans were identified as cost effective plans; 6 were identified as best buy plans. Figure 4-2 displays the cost effective plans, and Figure 4-3 displays the best buy plans. The best buys are the range of plans which provide the best investments for producing habitat units – of all possible restoration options; they provide the most habitat units per dollar invested.

FIGURE 4-1: All 192 Alternative Habitat Restoration Plans

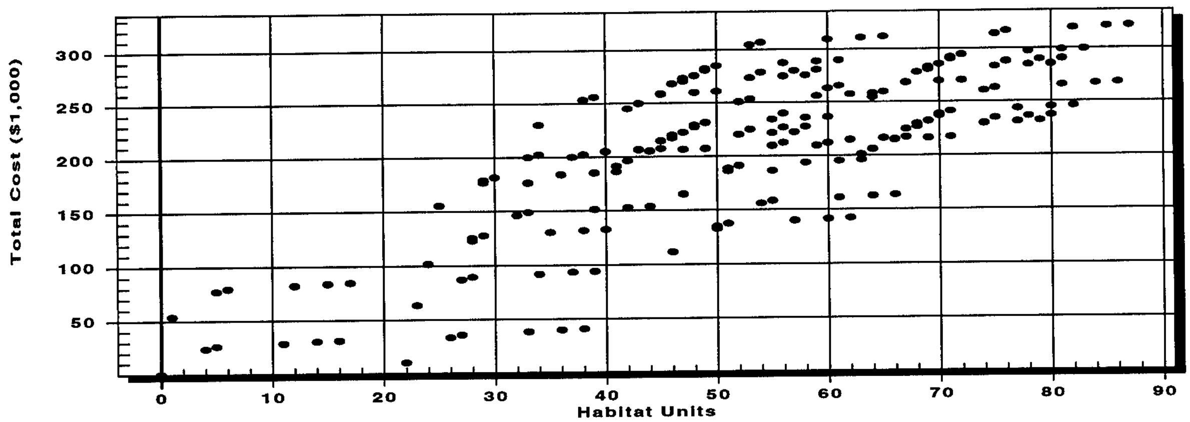


FIGURE 4-2: 26 Cost Effective Habitat Restoration Plans (6 Best Buys are indicated by stars)

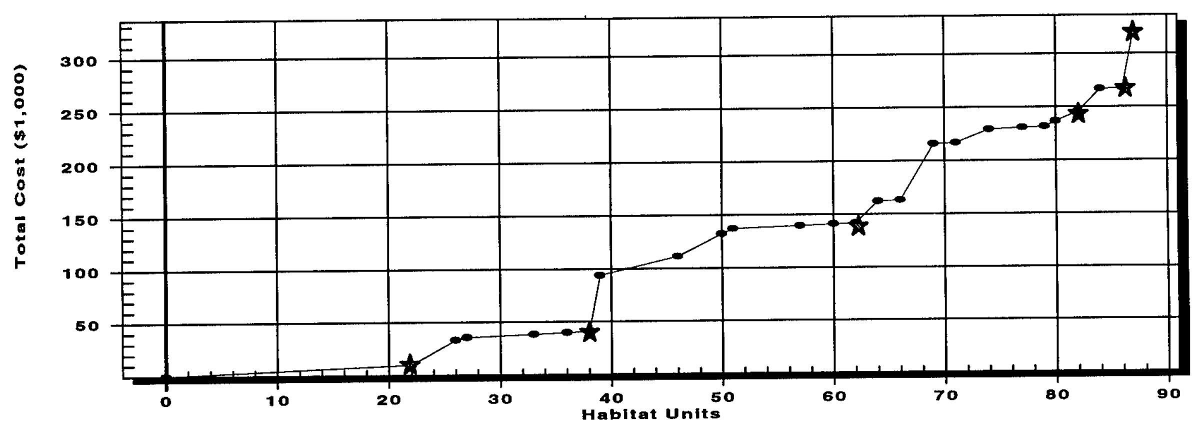
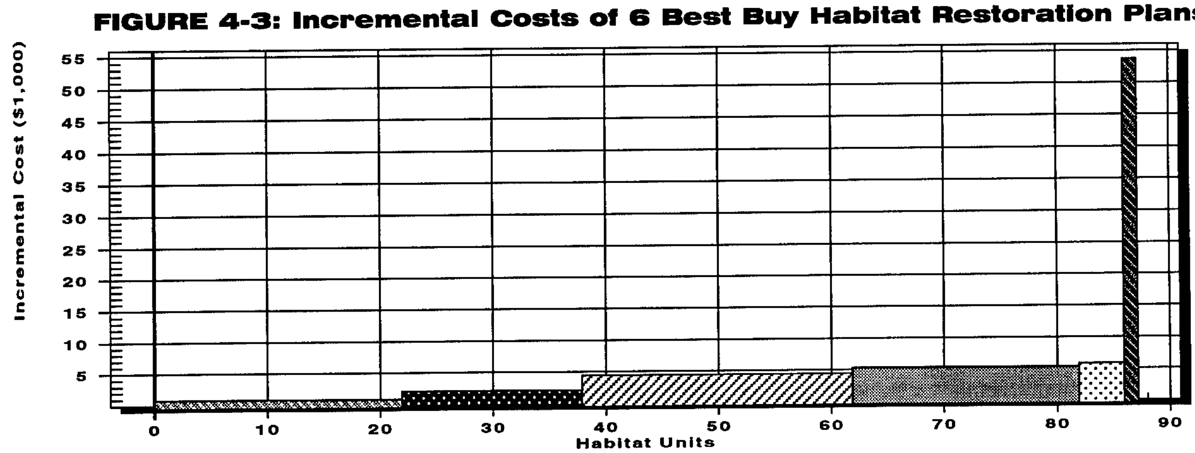


FIGURE 4-3: Incremental Costs of 6 Best Buy Habitat Restoration Plans



What's the best combination of multiple solutions at multiple sites?
Example C - Battlefield Park Improvements

Planning Problem. A Civil War battlefield in a mid-Atlantic state has been preserved as a National Battlefield Park. In updating the park's master plan, a number of different improvements were considered to restore the area to its Civil War-era conditions and enhance park visitors' experiences.

Solutions, Costs and Outputs. The ten park improvements considered are listed in Table 5. Different scales of improvement were considered for restoration of five historic houses (from exterior, to interior, to lawn restorations) and restoration of historic roads (two phases of work). Historic landscape features could be restored throughout the park. New interpretive exhibits could be located in either a remodeled central visitors' center or at three new exhibit sites on the battlefield. A dilapidated storage building could either remain in place or be removed if a nearby maintenance building were remodeled with expanded storage space. The cost of each improvement was estimated and included costs for planning, design, construction and contingencies. For the purpose of this analysis, the benefits of park improvements were estimated, based on expert judgment, using historic value index units. These units were on a scale of 10 to 0, with 10 representing the greatest improvement in visual and visitation values, and 0 representing no improvement. Table 5 displays the estimated costs and outputs of the ten park improvement options.

TABLE 5: Solutions, Costs, and Outputs

Park Improvements		Cost ($1000)	Outputs (historic value index units)
No Action		0	0
Restore Historic Homes.	Exterior restorations.	950	7
	Exterior & interior restorations.	1,800	8
	Exterior, interior & lawn.	2,100	9
Restore historic landscape features.		945	7
Restore Roads.	First phase improvements.	2,140	8
	Second phase improvements.	3,000	9
Remodel visitors' center.		265	3
Site #1 interpretive exhibit.		366	6
Site #2 interpretive exhibit.		255	6
Site #3 interpretive exhibit.		93	5
Cemetery parking and landscaping.		70	2
Remodel maintenance building.		25	1
Remove dilapidated storage building.		32	4

Formulation. This case represents the most complex type of plan formulation problem. It includes multiple scales of solutions (three levels of restoration of historic houses, and two phases of road improvements), a combinability constraint (the remodeled visitors' center is not combinable with any of the three site-specific exhibits), and a dependency constraint (removing the dilapidated storage building is dependent on remodeling the maintenance building). If the combinability and dependency constraints are not considered, it is possible to formulate 3,072 different alternative plan combinations. Imposing the constraints reduces the number of combinations to the 1,296 plans displayed in Figure 5-1.

Screening. Thirty-two of the 1,296 possible plans were identified as cost effective plans; and 9 were identified as best buys. Figure 5-2 displays the cost effective plans, and Figure 5-3 displays the best buys. Of all possible options, the best buys are the best investments for providing historic value index units.

FIGURE 5-1: All 1,296 Alternative Park Improvement Plans

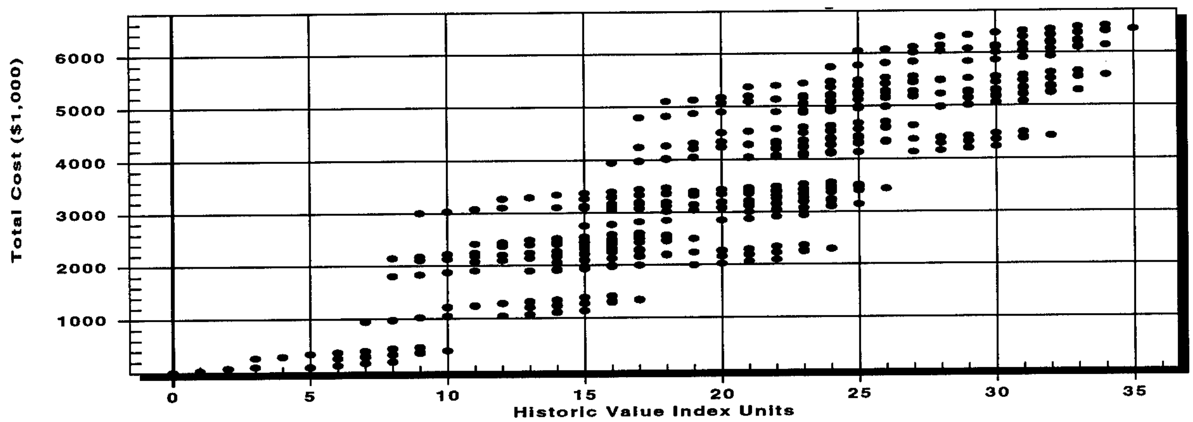


FIGURE 5-2: 32 Cost Effective Park Improvement Plans (9 Best Buys are indicated by stars)

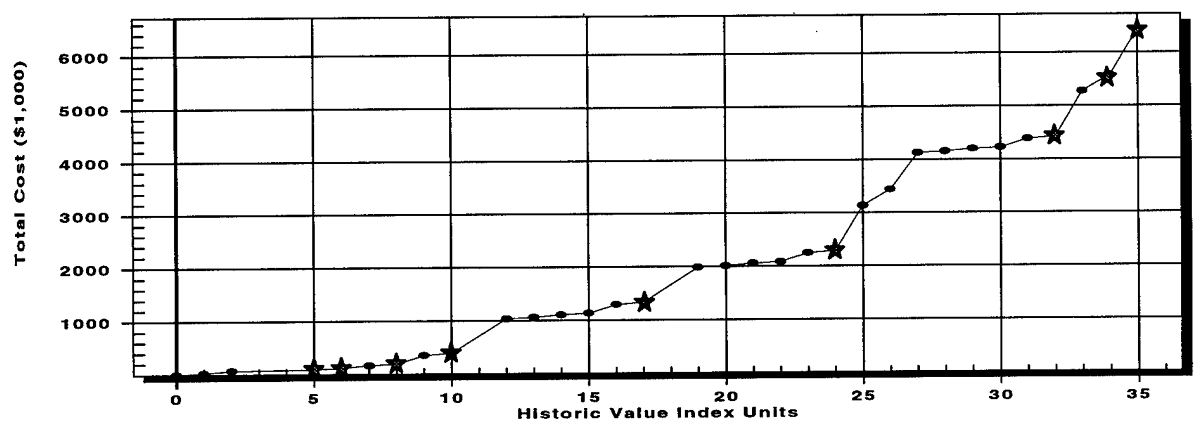
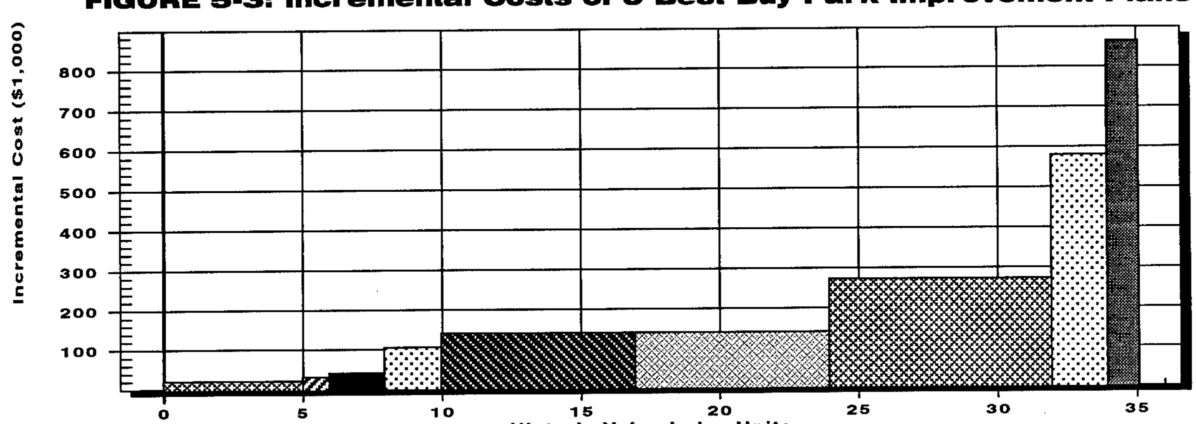


FIGURE 5-3: Incremental Costs of 9 Best Buy Park Improvement Plans



Selection...What's "Worth It?"

In the end, the question is quite simply, "what's worth it?" How many hazardous materials cleanup points should we invest in? How many lake habitat units are worth it to restore? How much should we spend to increase a park's historic values? Cost effectiveness and incremental cost analyses will not, of themselves, reveal the best solution in answer to such questions. The analyses will, however, provide decision makers with more information to compare, assisting them in selecting a plan based on what they believe to be "worth it." The relationship of changes in cost to changes in output revealed through the analyses, together with other decision criteria such as output targets and thresholds, cost constraints, uncertainty in cost and output estimates, and consideration of unintended effects, will assist decision makers in making a more informed selection decision. More informed decisions should be better decisions, leading to better results for our Nation's increasingly scarce financial and environmental resources.

Resources

The following resources for conducting cost effectiveness and incremental cost analyses for environmental planning are available from the US Army Corps of Engineers' Institute for Water Resources in Alexandria, Virginia. These resources include instruction in both environmental plan formulation and in cost effectiveness and incremental cost analyses. The ECO-EASY and IWR-PLAN software programs automate the step-by-step procedures described in the manuals and include formulation and screening features.

- "How To" Manuals
  - *Cost Effectiveness Analysis for Environmental Planning: Nine EASY Steps.* October 1994. IWR Report 94-PS-2.
  - *Evaluation of Environmental Investments Procedures Manual, Interim: Cost Effectiveness and Incremental Cost Analyses.* May 1995. IWR Report 95-R-1.
- Computer Software
  - *ECO-EASY: Cost Effectiveness and Incremental Cost Anlayses Software, Beta Version 2.6.* May 1995. Institute for Water Resources and Waterways Experiment Station.
  - *IWR-PLAN Decision Support Software, Beta Version 1.5.* December 1997.
- Case Study Report
  - *Bussey Lake: Demonstration Study of Incremental Analysis in Environmental Planning.* December 1993. IWR Report 93-R-16.

Check for document and software availability on IWR's homepage: www.wrc-ndc.usace.army.mil/iwr

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*The views expressed in this paper are those of the authors and not necessarily those of the Department of Defense or of the United States Army.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
January 1998

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Making More Informed Decisions in Your Watershed When Dollars Aren't Enough

5. FUNDING NUMBERS

6. AUTHOR(S)
Kenneth Orth, Ridgley Robinson, and William Hansen

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USACE, Water Resources Support Center
Institute for Water Resources
Casey Building, 7701 Telegraph Road
Alexandria, VA 22315-3868

8. PERFORMING ORGANIZATION REPORT NUMBER
IWR Report 98-R-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Headquarters, U. S. Army Corps of Engineers
Directorate of Civil Works
20 Massachusetts Avenue, NW
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, (703) 487-4650

12a. DISTRIBUTION/ AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
Decisions regarding potential investments in watershed resources can leave decision making comparing "apples to oranges" when the costs of watershed improvements are measurable in dollars but the benefits are not. While traditional benefit-cost analysis simply won't work in these situations, the tools of cost effectiveness analysis and incremental cost analysis can help by providing information to support decision making. This paper presents a general analytical procedure for cost effectiveness and incremental cost analyses, and three example applications. The examples demonstrate the procedures applicability to planning for investments in a variety of resources as well as problem solving situations of different complexities.

14. SUBJECT TERMS
Cost Effectiveness Analysis, Incremental Cost Analysis, Planning, Watershed, Decision Making

15. NUMBER OF PAGES
18

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (rev 2-89)
Prescribed by Ansi Std. 229-18
298-102